Chapter 8
Robust Fuzzy Digital PID Controller Design:
A Contribution for Advanced Studies in Control and Automation

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ABSTRACT

A robust fuzzy digital PID control methodology based on gain and phase margins specifications is proposed. A mathematical formulation based on gain and phase margins specifications, the Takagi-Sugeno fuzzy model of the process to be controlled, the structure of the digital PID controller, and the time delay uncertain system are developed. A multiobjective genetic strategy is defined to tune the fuzzy digital PID controller parameters, so the gain and phase margins specified to the fuzzy control system are found. An analysis of necessary and sufficient conditions for fuzzy digital PID controller design with robust stability, with the proposal of the two theorems, is presented. Experimental results show the efficiency of the proposed methodology in this chapter, applying a platform control in real time of a thermic process through tracking the reference and the gain and phase margins keeping closed the specified ones.

INTRODUCTION

A control system is designed to perform two essential functions: modeling the system response in a desired reference and keeping this behavior besides the uncertainties affecting the system. This latter, called robustness to uncertainty, is essential for the control system reliability. However, for the successful control design, the controller is normally designed from the real process model, based on robustness and stability criteria (Bartoszewicz, 2011).

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Since 1980, fuzzy systems have been applied in modeling and control of dynamic systems. Among several types of fuzzy systems, there is a very important class called Takagi-Sugeno (TS). Recently, it became a powerful tool applied to modeling and control (Qi & Brdys, 2005). This is due to structure based on rules that allows approximation of functions, nonlinearities and uncertainties as well (Qi & Brdys, 2005; Azeem, 2012).

Conventional PID controller is very applied yet due its structure relatively simple, and parametric adjustment for guaranteed stability and confiability in several applications (Xu et al., 2011). However, in industrial processes with nonlinearities, parametric variations and uncertainties, the adjustment of PID controller parameters becomes difficult, so the robustness requirements are not attended. Due that, the fuzzy PID controller became as alternative for control systems design so guarantee robustness and high performance requirements, once its rules structure allows treatment of dynamic complexities in the process to be controlled (Arulmozhiyal & Kandiban, 2012; Bo et al., 2010; Xiong & Wang, 2012).

The proposed methodology in this chapter consists in a model based fuzzy robust digital PID controller design from the gain and phase margins specifications. The mathematical formulation based on fuzzy Takagi-Sugeno structure and PDC strategy, is presented. From a multiobjective genetic algorithm, the PID subcontrollers parameters are obtained according to the gain and phase margins specifications and the fuzzy model parameters of the process to be controlled. The necessary and sufficient conditions for fuzzy digital PID controller design, from robust stability criteria, with proposal of two theorems, as well as experimental results for real time robust fuzzy PID control of a thermic process, are presented.

BACKGROUND

New methodologies have been developed to ensure high performance in control systems. Reaching this objective in front of uncertainties is not a trivial task, and still constitutes a challenge in the control theory. Especially, the robust control theory has received great interest from scientific community to develop controllers to deal with complex dynamics such as nonlinearities, uncertainties, time delay, among others, and guarantee robust control design (Mueller, 2011).

Nowadays, the interest for strategies to model and control of complex process has been motivated by the following factors (Serra, 2012):

- Development of efficient identification methods and greater applicability of computational resources;
- Improvement of softwares and hardwares technologies, making it possible to incorporate complex models in the control systems design.

The robust control theory has grown remarkably in recent years, gaining ground even in the industrial environment where it is a valuable tool for analysis and dynamic systems design (Wu et al., 2010). Due to its practical applicability, the control theory is used in solving engineering problems and it has been applied in several areas where practical requirements of performance are relevant (Zhong, 2006; Serra, 2012).

Thus, given the need for designers and engineers dealing with process increasingly complex, taking into account dynamic and structural characteristics such as nonlinearities, uncertainties, parametric variations, time delay, among others, several robust control methods have been proposed, allowing in